Quality and Yield of Roe from Impounded Herring

H. Tsuyuki and J. Y. H. Cheng

Department of Fisheries and Oceans
Fisheries Research Branch
Vancouver Laboratory
6640 N. W. Marine Drive
Vancouver, British Columbia V6T 1X2

October 1985

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1408

86-1512/

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences No. 1408

October 1985

QUALITY AND YIELD OF ROE FROM IMPOUNDED HERRING

by

H. Tsuyuki and J. Y. H. Cheng

Department of Fisheries and Oceans

Fisheries Research Branch

Vancouver Laboratory

6640 NW Marine Drive

Vancouver, British Columbia V6T 1X2

(c)Minister of Supply and Services Canada 1985

Cat. No. Fs 97-6/1408E ISSN 0706-6457

Correct citation for this publication:

Tsuyuki, H. and J. Y. H. Cheng. 1985. Quality and yield of roe from impounded herring. Can. Tech. Rep. Fish. Aquat. Sci. 1408: 25p.

TABLE OF CONTENTS

	Page
ABSTRACT	iv
INTRODUCTION	1
MATERIALS AND METHODS	1
SOURCES OF HERRING	1
SAMPLING	1
ROE PROCESSING	2
A) brine firming method	2
B) freezing method	2
QUALITY EVALUATION	3
GRADING	3
FIRMNESS DETERMINATION	3
ROE COMPOSITION ANALYSIS	4
Nitrogen, Moisture, Total ash, Lipid, Salt content	4
RESULTS AND DISCUSSION	5
1981 IMPOUNDMENT	5
1982 IMPOUNDMENT	5
1. Roe quality during maturation	5
2. Proximate composition during maturation	5
3. Roe yield	6
1983 IMPOUNDMENT	7
SENSORY EVALUATION	7
DEVELOPMENT OF LIVE FISH PUMPING SYSTEMS	8
SUMMARY	9
ACKNOWLEDGEMENTS	9
REFERENCES	10
TABLES	13
FIGURES	23

ABSTRACT

Tsuyuki, H. and J. Y. H. Cheng. 1985. Quality and yield of roe from impounded herring. Can. Tech. Rep. Fish. Aquat. Sci. 1408: 25p.

Processed herring roe were produced from each of the three experimental impoundment operations carried out by the Pacific Biological Station over three successive years from 1981 to 1983. These roe were at least normal in quality by commercial standards. During maturation of the impounded herring, roe which were mature resulted in high grade processed product with little or no fragility even in the presence of high levels of immature roe. In the 1982 and 1983 impoundment studies, the moisture content of fresh frozen roe ranged respectively from 67.2 to 77.8% and 68.3 to 78.8%, proteins from 16.9 to 26.2% and 16.4 to 25.1%, lipids from 2.9 to 6.0% and 1.9 to 4.6%, and ash from 1.0 to 1.9% and 0.9 to 1.3%.

The proportion of high quality processed roe reached the maximum when the moisture content of fresh roe reached high levels. This period corresponded to the 3rd week of March for the 1982 impoundment and slightly earlier the subsequent year. In both years this was approximately one week after the plateau level on the gonosomatic index curve was reached.

Processed roe from once-frozen and from brine-firmed herring averaged respectively, 66.8 and 62% moisture and 13 and 17% protein. Roe from once-frozen impounded herring gained 21% in weight while those from previous studies on experimental samples gained from 12 to 20%. In color, the the processed roe ranged from 2.5Y 8/4 to 2.5Y 8/8 by Munsell color notations; by tristimulus readings, L = 42-57, a = 3-5 and b = 20-23. All processed mature roe were firm to the touch and registered a mean value of 2.65 ± 0.76 kg/cm by the Ottawa Texture Measuring System.

Through impoundment, harvesting can be extended for a period of at least 3 weeks and the amount of immature roe can be minimized. It is suggested that a suitable high capacity pumping system may facilitate live fish transfer from seine to transport vessel and from it to impoundment site.

RESUME

Tsuyuki, H. and J. Y. H. Cheng. 1985. Quality and yield of roe from impounded herring. Can. Tech. Rep. Fish. Aquat. Sci. 1408: 25p.

Chacune des trois expériences de mise en captivité menées par la station de biologie du Pacifique durant trois années consécutives (de 1981 à 1983) a permis de produire des oeufs de hareng traités. Selon les normes commerciales, la qualité de ces oeufs était au moins normale. Durant la maturation des harengs captifs, les oeufs qui étaient matures ont donné un produit traité de haute qualité peu ou pas fragile, même en la présence de grandes proportions d'oeufs immatures. Au cours des études, les oeufs frais congelés contenaient de 67.2% à 77.8% et de 68.3% à 78.8% d'humidité, de 16.9% à 26.2% et de 16.4% à 25.1% de protéines, de 2.9% à 6.0% et de 1.9% à 4.6% de lipides ainsi que de 1.0% à 1.9% et de 0.9% à 1.3% de cendres pour les années 1982 et 1983 respectivement.

La proportion d'oeufs traités de haute qualité a atteint un maximum lorsque la teneur des oeufs frais en humidité a atteint des niveaux élevés. Cette période correspondait à la troisième semaine de mars dans le cas de l'expérience de 1982 et à un petit peu plus tôt en 1983. Dans les deux cas, cela s'est produit environ une semaine après que le palier de la courbe de l'indice gonosomatique eut été atteint.

Les oeufs traités provenant de harengs ayant déjà été congelés et de harengs rendus fermes en saumure avaient respectivement des moyennes de 66.8% et 62% d'humidité, ainsi que de 13% et 17% de protéines. Le poids des oeufs provenant de harengs captifs ayant déjà été congelés a augmenté de 21% alors que dans les expériences effectuées précédemment sur des échantillons, les résultats variaient de 12% à 20%. La couleur des oeufs traités variait de 2.5J 8/4 à 2.5J 8/8 selon le guide de couleur Munsell; les résultats obtenus en fonction des trois critères chromatiques étaient les suivants: L = 42-57, a = 3-5, et b = 20-23. Tous les oeufs matures traités étaient fermes au toucher et avaient une valeur moyenne de 2.65 ± 0.76 kg/cm dans le cadre du système de mesure de la texture (Ottawa).

Grâce à la mise en captivité, il est possible de prolonger la récolte d'au moins trois semaines et de réduire la quantité d'oeufs immatures. Il est proposé d'utiliser un système de pompage à grand débit pour faciliter le transfert des poissons vivants de la senne au bateau de transport, et de celui-ci au parc.

INTRODUCTION

In 1981 a program was initiated at the Pacific Biological Station to examine the more critical biological and technological aspects of capturing, transporting and impounding maturing herring for the purpose of harvesting roe away from the natural spawning grounds. This type of operation could also be useful as a convenient source of food herring and live bait for the sports fishing industry. Impoundment permits the voiding of feed and minimizes post-mortem proteolysis of the abdominal walls for food herring production.

An important aspect of the impoundment operation is the quality of roe that can be produced in comparison to that from natural harvest. In addition the impoundment operation provided an excellent opportunity to follow changes in roe quality and yield during the entire period of gonadal development to partial spawning. This report describes the study carried out by the Technology Services Branch on the quality and overall yield of herring roe from the impoundment operations of 1981 to 1983.

MATERIALS AND METHODS

SOURCES OF HERRING

Herring were captured by seine between early January and February in Stuart Channel, Gulf Island region during 1981 to 1983. Details of capture sites and live transport methods, sea pen holding facilities, environmental conditions and feeding regimes of herring used for the roe quality studies during each of the 3 years of impoundment investigations are described by Brett and Solmie (1982) and by Kreiberg et al. (1982, 1984).

SAMPLING

1) Initial sampling was carried out on March 5th, 1981. Herring samples ranging in weight from 10 kg (usually estimated at about 7 fish per kg) to 20 kg were taken randomly at 3 or 4 day intervals from impoundment pen H4 (Brandon Island fish farm, Departure Bay). Sampling was increased to daily on the 3rd week of March when most of roe herring were approaching maturity.

2) Sampling of 15 kg to 30 kg lots of herring from sea pen H7 (monitor pen for L1) was commenced on January 28th, 1982, and continued every 3 to 4 days until April 15th when spawned out fish appeared. Sampling was continued weekly from pen L2 from April 15th to May 12th, 1982.

3) Sampling of 10 kg to 30 kg lots of herring from the sea pen at the Ruxton Island field site was started on March 1st, 1983, and continued every 3 to 4 days until their release on March 23rd. Weekly samples were also taken from pen H4 at the fish farm on Brandon Island from March 29th until May 2nd, 1983.

Roe herring was either quick frozen soon after sampling, or brine processed within 6 hours post-mortem storage in ice.

ROE PROCESSING

A) Brine firming method

This method involved immersion of whole herring in brine (10-15%, w/v) for 3 to 4 days at around 5°C at a fish to brine ratio of 2:1 (kg/l). By this time, the roe usually became firm enough to remove (Boyd et al. 1980). The roe obtained in this way, referred to as primary processing in this study, was rinsed with water 2 to 3 times, depending on its state of cleanliness, and placed in 10% brine for 12 to 16 hours. After draining briefly, the roe was transferred to saturated brine (26 to 28% salt, w/v) for a day. If required, the solution was changed with fresh brine before fortifying with additional salt to ensure saturation during the curing process. After a few days in saturated brine at around 5°C the roe was ready for grading and assessment of quality. This curing step of roe is referred to as secondary processing. After draining well for approximately 2 hours, the roe yield was recorded. Salt penetration into the roe continued beyond the 2 days usually allowed for curing in saturated brine before draining and weighing. Roe weight continued to increase slightly for a few more days (see Table 6).

B) Freezing method

Samples of April 13th and 21st, 1981, were packed in polyethylene bags, the open end folded and closed by stapling. The herring packages were placed in single layers on metal shelves for 1 to 2 days in an air-blast freezer room controlled at -40°C. Thermocouples placed in the fish positioned near the center of the bag indicated that the core temperature was down to -30°C within the first day using this method (Tsuyuki et al. 1977; Tsuyuki and Cheng 1985). The frozen herring were stored in a freezer room maintained at -24 to -28°C for a period of 1 to 2 months. Most of the 1982 and 1983 samples were frozen in plastic buckets in the freezer at the Pacific Biological Station for up to one week and transferred to the freezer at the Vancouver Laboratory under the same holding conditions and duration of time as the 1981 samples. The frozen herring were air-thawed at room temperature (20 to 22°C) for 1 to 2 days or thawed by running cool tap water. The removal of roe and brine processing was carried out in the usual manner.

QUALITY EVALUATION

GRADING

The term "mature" roe as used here refers to those which become firm after primary and secondary processing, while "immature" or "unripe" roe refers to those which remain soft and will not become firm.

Processed roe was graded subjectively according to the following system:

Grade I - Light yellow to yellowish-brown in color, no uneven discoloration in roe, fully shaped and over 10 cm (about 4") long by 2.5 cm (about 1") wide, about 1 cm or more in thickness, weight over 20 g per skein, firm to the touch, no off odor or bitter rancid flavor.

Grade II - Roe is between 6 to 10 cm (2.5" to 4") in length, medium size, fully shaped or slightly damaged (broken).

Grade III - Roe is under 6 cm, small size, fully shaped or broken.

Grade IV - Irregularly shaped or broken pieces under 4 cm long.

Grade V - Immature (unripe) roe, fragile and/or soft-spongy roe.

FIRMNESS DETERMINATION

Firmness of processed roe was evaluated with the Ottawa Texture Measuring System (OTMS), using a Model D-1203, manufactured by Canners Machinery Ltd., equipped with a Daytronic transducer-amplifier-indicator and a strip chart recorder. An aluminum plunger, 1.0 cm in diameter, was used as the upper portion of a compression test cell. With the speed control setting at 20 (a crosshead speed of approximately 1.4 cm/min) and a recorder chart speed of 50 mm/min, the test roe, with the flat side supported on an aluminum plate, was compressed to a thickness of about 4 mm to deform the egg segments in the middle region of the skein. The instrument was operated at 10% range of the maximum calibrated load capacity of 200 kg to provide sufficient sensitivity at a reasonable testing rate. A typical force-deformation curve of grade 1 roe is shown in Figure 1.

Roe firmness was defined as the maximum slope (kg/cm) of the force-deformation curve. The bioyield value was taken as the force at which there was a sudden decrease in the force sustained by the roe due to tissue rupture of the egg segments. Deformation was defined as the travel distance of plunger from initial contact with the roe surface to the bioyield point. The firmness of the roe for each 10 or more random skeins tested was averaged.

ROE COMPOSITION ANALYSIS

Nitrogen determination:

Nitrogen analysis was carried out by the Kjeldahl Method (AOAC, 1980). Occasionally the modified procedure by Concon and Soltess (1973) was also applied. Portions of sample from the central segments of 6 randomly selected skeins of roe were used for the determination. Mean value of protein content was expressed by multiplying the total nitrogen value (N) by 6.25, (N x 6.25).

Moisture determination:

The sample remaining from nitrogen analysis was ground into small pieces by mortar and pestle or by a Parch II meat grinder and mixed well. Approximately 10 g portions were weighed accurately into a suitable pre-weighed crucible and dried to constant weight in an oven at 105°C for 12 to 16 hours.

Total ash determination:

After moisture determination, the dry sample was heated on a hot plate in a fume hood. When the charred mass was in a suitable condition, it was transferred to a muffle furnace maintained at 550°C (450°C for processed roe because of the presence of chlorides) until all the carbon had been combusted. After cooling to room temperature, the crucible plus ash was then transferred to a desiccator and reweighed. The total ash was calculated as a percentage of the original sample.

Lipid determination:

Total lipid was extracted from 10 to 30 g of roe homogenate by the method of Bligh and Dyer (1959).

Sodium chloride determination:

The sodium chloride content in the roe was estimated with the Quantab Chloride Titrator (No. 1175 or 1176). Samples of 10 g were used in the dilution/extraction procedure as recommended by the manufacturer. Mean value from 6 different roes was determined for a single replication.

RESULTS AND DISCUSSION

1981 IMPOUNDMENT

Initial sampling from pen H4 was carried out on March 5th, 1981. By that time, the fish had recovered from stress of capture and appeared to be in excellent condition. The proportion of immature roe was over 30% based on number of skeins (Table 1). These immature roe did not become firm after secondary processing and were therefore of low quality. Ovaries, occupying almost two-thirds of the ventral cavity, were evaluated at stage II to IV on the International (Hjort) Scale of maturity of the herring gonad (Bowers and Holliday 1961). By the end of March (Table 1) the proportion of immature roe decreased to 2% or less. The percentage of high quality mature roe, from the processing standpoint, approached a maximum value a few days after the gonosomatic index reached the plateau level (Fig. 2). Mature roe from the earlier samples with relatively high proportion of immature roe was nevertheless firm and of high quality. The percentage of roe in grades I, II and III varied in samples, mainly due to differences in the proportions of smaller herring in the samples. After March 18th, the percentage of grade I roe exceeded more than half of the total.

1982 IMPOUNDMENT

1) Roe quality during maturation

Roe from samples taken from January 28th to February 24th fell within stages III to V of the Hjort scale (Table 2). The proportion of herring roe in the immature stage of development decreased rapidly from over 80% in samples on March 1st to a level of under 5% in samples on March 23rd and later. The proportion of good quality roe reached high levels from the 3rd week of March to the 3rd week in April. The sum of the percentages of grade I and II roe ranged from 71 to 89% during the peak period. Although partially spawned roe herring was observed in samples from pen L2 on or after April 15th, the quality of most processed unspawned roe was still good even on May 12th when a quarter of the roe herring was completely spawned out (Table 2).

2) Proximate composition during maturation

The moisture content of the fresh frozen roe ranged from 67.2 to 77.8% while the protein content ranged from 16.9 to 26.2% (Table 3). The total ash varied from 1.0 to 1.9% and lipid from 2.9 to 6.0%. During the sampling period, the moisture content of roe was the lowest on February 24th. It remained near this level until March 4th when a steady increase occurred with increasing maturity. Relatively constant high moisture values were

observed from March 25th until the final sampling date. The highest quality roe corresponded approximately to the stage when moisture values were the highest. The protein content decreased with increasing moisture and reached a somewhat steady value.

Proximate composition of the processed roe was normal (Table 4) compared to commercially available samples or wild stocks. Processed roe obtained from once-frozen herring averaged 66.79% moisture, 13.03% protein and 17.80% ash while brine processed roe averaged 61.97% moisture, 17.17% protein and 17.13% ash (Table 4). Higher moisture and lower protein contents were found in the processed product from once-frozen roe herring from both impoundment and commercial samples.

3) Roe yield

The final yields of processed roe from brine-firmed and from once-frozen herring are compared in Table 5. From primary to secondary processing, roe from brine firmed herring increased from 21.24% to 24.93%, a 17.4% increase. Those from frozen fish increased from 25.9% to 31.43%, a 21.4% increase.

For comparison, unpublished data of 1978 - 79 on roe weight gains for herring captured from different areas are presented in Table 6. The initial roe weight was determined for fresh herring immediately upon delivery. As roe from fresh herring are extremely soft and readily damaged, a scalpel with a No. 60 blade modified to protect the back side from tearing the ovaries, was used for excision. The skeins of roe were removed with care and weighed. From frozen samples, roe were excised from partially thawed fish and weighed. The initial yields from fresh and frozen fish were usually comparable.

To calculate the initial roe yield from herring immersed in 11% brine, it was necessary to determine the extent of shrinkage of the females because the original fish weight must be compared on the same basis as for fresh and frozen samples. The proportion of females in the brine firmed sample could be estimated accurately only after sex determination at the time of roe removal. Only mature roe firm during the brine firming step. The gonads of males and immature females do not become firm. The original weight of female fish before immersion in brine was obtained by multiplying the combined weights of female carcasses and roe by the ratio of the original sample (male + female) weight over the drained weight of sample after immersion in brine.

Both the initial and final percent yield of roe from brine-firmed herring from northern British Columbia (Kitkatla Inlet) and the two samples from Washington State were lower than those from frozen fish (Table 6). From frozen fish the increase in the weight of roe after final curing in brine ranged from 12 to 20%. Increases of this magnitude are often encountered in experimental samples which can be quick frozen shortly after harvest (Tsuyuki et al. 1979; Huynh and Howard 1981; Tsuyuki and Cheng 1985, in press) while increases from samples obtained from commercial landings could be very much

lower (Tsuyuki et al. 1977). Only slight increases in the final cured product are obtained from roe extracted from fresh herring. It could be of practical significance that further increases in the final weight occur when roe is equilibrated in fully saturated brine for periods longer than the 2 days often allowed in industry. While it is generally true that higher yields of final roe products can be obtained from frozen herring than from brine firmed herring an accurate comparison must take into account the known higher percent roe yield from larger fish (Hay 1985; Tsuyuki and Cheng 1985). Not only must post-mortem age, handling, storage and freezing rates be comparable but also such studies should be carried out on fish selected for the same size range.

1983 IMPOUNDMENT

Sampling of herring from the impoundment at the Ruxton Island field site was started on March 1st. The proportion of roe in the immature stage of development was high and decreased from over 85% on March 1st to a level of about 5% or lower in the samples of March 18th and thereafter (Table 7). The amount of good quality roe approached the highest level just before the 3rd week of March and for several weeks thereafter. The sum of the percentages of grade I and II roe ranged from 59% to 85% during the peak period. It was noted, however, that grade III roe was relatively high, indicating a significant proportion of the impounded herring examined were of small size. The small amount of fragile roe observed in the earlier samples was included in grade V, the immature category. Spongy roe, encountered under poor handling, freezing or processing practices (Tsuyuki et al. 1977; Tsuyuki and Cheng 1985, in press) were not observed in the processed product from frozen herring in the 1983 study, indicating that good post-mortem procedures prevailed.

Partially spawned roe herring was observed earlier (March 22nd) from samples at the Ruxton Island field site, and later (April 14th) from samples from pen H4 at the fish farm. The quality of most processed roe was still good until May 2nd when about 17% of the roe herring was completely spawned out. Proximate composition of roe was in the normal range; moisture content ranged from 68.3% to 78.8%, protein from 16.4% to 25.1%, lipid from 1.9% to 4.6%, and total ash from 0.9% to 1.3% (Table 8).

SENSORY EVALUATION

Sensory evaluation of processed roe from impounded herring was carried out by a procedure similar to the Hedonic Scale Method (Peryam and Pilgrim 1957) using a 5 point verbal categorization by 3 to 5 experienced panel members and by more than 20 cumulative untrained persons. The most favorable response "like very much" was given by all the experienced panel members. They further indicated that roe processed from brine firmed fish had the best eating quality. Those processed from frozen fish had a desirable translucent bright-fresh appearance.

In general, the characteristic crunchiness of processed mature roe was recognized most of the time by the trained panelists. The test subjects preferred the product light yellow to yellowish-light brown in color. In terms of Munsell color notation, these roe ranged from 2.5Y 8/4 to 2.5Y 8/8. Discoloration of processed roe, characterized by green tipping, black tipping and dark brown roe has been encountered occasionally in commercial sources (Bilinski et al. 1975; Huynh and Howard 1981). However we observed only two pairs of green tip roe in the impounded samples during the three year period of study. Under large scale commercial operations, the incidence of green tipped roe would be expected to be higher. Although some difference in color was observed with roe from impounded herring (see remarks in Table 1), this variation was acceptable to the panelists. It was our opinion that the processed roe from impounded herring was within the normal range values (L = 42 to 57, a = 3 to 5, b = 20 to 23, a/b ratio from 0.20 to 0.26) if the color of roe were evaluated by a tristimulus apparatus. Previously unpublished Hunter Colorimeter data for roe processed or treated by several different methods are included here to provide some idea of the range of values that could be obtained by these measurements (Table 9). In that study a Hunter D25 Color and Color Difference Meter, calibrated with a yellow standard, L = 83.0, a = -4.8 and b = 26.0, was used. The roe were arranged closely together in a modified clean plastic container (bottom plate; 12.5 cm x 12.5 cm x 2 mm in thickness). The whole sample unit was covered with a black lid and L, a and b values were measured in duplicate for each sample which were rotated 90° between readings. Aliquots of 3 to 5 subsets of the same lot were taken randomly for measurement.

All the processed mature roe were firm to the touch. Samples taken from grade I and some grade II roe during the peak period of the 1983 season were subjected to a firmness evaluation by the Ottawa Texture Measuring System. Over 90% of the roe tested showed a distinct deformation peak as illustrated in Figure 1. The mean value of roe firmness was 2.65 ± 0.76 kg/cm (n = 54), while the mean value in the weight of the skein of roe was 28.37 ± 5.36 g as shown in Table 10.

DEVELOPMENT OF LIVE FISH PUMPING SYSTEMS

Pumping systems, essential for moving large volumes of fish post-mortem, have been used in the herring fishery for a number of years. Various degrees of physical damage to the carcasses have generally been associated with all pumping systems. In food herring more so than in roe herring operations, it is important to minimize physical damage to fish. Several types of pumps have been evaluated by Gillis (1979), Gillis et al. (1982), and by Lee (unpublished data). Modifications in the impeller type of pumps were recommended by Gillis et al. (1982) to reduce the considerable physical damage inflicted on food herring.

For a full realization of an impoundment operation for herring, a high capacity live fish pumping system is required which can function effectively in weather conditions typical during the fishery. These systems

are required for the rapid transfer of live herring from seines to transport vessel, followed by unloading into sea pens. Pumping systems for live fish must not inflict any physical damage which may reduce survival and requires a level of performance not yet successfully tested on this species by previous studies. The feasibility of live pumping of herring and juvenile salmon has been investigated by the Technology laboratory for some years (F. N. Lee, unpublished data). Two systems, the jet-assisted air-lift and the air-lift pumps have been tested and the damage inflicted to the fish evaluated. The jet-assisted air-lift pump, originally designed for operational convenience in the handling of fish post-mortem, and predicted to be harsher on live fish passing through the system, was tested initially. However, this pump caused unacceptable damage to live fish and mortality was high. The air-lift system, often used by industry to unload herring and salmon post-mortem, and by operational principles one of the gentlest and least damage inflicting pumps in existence, was modified and tested by Lee (unpublished data) and found to cause little or no damage to both live herring and young salmon. Only a larger scale field trial remained to be investigated at the time of termination of the program in 1984. The potentiality of using the air-lift system for live fish transfer in impoundment operations for herring or for other species appeared to show great promise.

SUMMARY

No diminution in the quality of processed product was observed from impounded herring. Several advantages can be realized by this technique of harvesting roe herring. The harvesting of immature roe can be minimized by test sampling from a more uniform population. Partially spawned roe can also be controlled more effectively through preliminary testing. Impoundment operations provide better opportunities for preservation of roe herring, resulting in higher quality processed product. Provided other stocks of fish with different spawning times are not added during the impoundment period, the harvesting period can be prolonged for 3 weeks or more resulting in a more controlled harvest, making effective use of processing capacity and labor. Impoundment provides the potential for diversification in the management of roe fishery. Improvement in the quality of herring for food can be realized through reducing proteolysis, commonly referred to as "belly burn" by allowing time for fish to void feed from the stomach before harvest.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Robert Kennedy and Ms. Elizabeth Mallett for sampling herring from the impoundment, and Ms. Wendy Coleridge and Mr. Greg Kawamoto for assistance in the proximate analysis.

The constructive comments of Dr. D. E. Hay during the preparation of the manuscript is greatly appreciated.

REFERENCES

Association of Official Analytical Chemists (AOAC). 1980. Methods of Analysis, 13th. ed.

Bilinski, E., L. ter Borg, D. Smith, M. Yamamoto and J. Zimmermann. 1975. Quality and quantity of roe obtained from Pacific coast herring under industrial processing conditions. Fish. Mar. Serv. Tech. Rep. 569: 22p.

Bligh, E. G. and W. J. Dyer. 1959. A rapid method for total lipid extraction and purification. Can. J. Biochem. Physiol. 37: 911-917.

Bowers, A. B. and F. G. T. Holliday. 1961. Histological changes in the gonad associated with the reproductive cycle of the herring (Clupea harengus L.). Marine Research No. 5. Dept. of Agriculture and Fisheries, Scotland.

Boyd, J. W., J. Cheng, M. D. Huynh, S. N. Williscroft and H. Tsuyuki. 1980. Roe herring processing: preservation and factors affecting firming of roe. Fish. Mar. Serv. Tech. Rep. 921: 26 p.

Brett, J. R. and A. Solmie. 1982. Roe herring impoundment research - report on the 1980/1981 studies. Can. Tech. Rep. Fish. Aquat. Sci. 1061: 51 p.

Cheng, J. Y. 1980. Internal report on colour measurement of processed Pacific herring roe.

Cheng, J. Y. and H. Tsuyuki. 1981. Internal report on herring roe yield studies.

Cheng, J. Y. and H. Tsuyuki. May, 1981. Report on quality of roe from impounded herring.

Concon, J. M. and D. Soltess. 1973. Rapid micro-kjeldahl digestion of cereal grains and other biological materials. Anal. Biochem. 53: 35-41.

Gillis, D. J. 1979. Ponding and other factors affecting the quality of herring for the food industry. Fisheries Management - Pacific Industry Report No. 109.

Gillis, D. J., C. A. Whiting, R. A. Radley, J. E. S. Wilcox, M. D. Ross and K. Jackson. 1982. Herring impoundment and pumping operations. Can. Ind. Rep. Fish. Aquat. Sci. 130: 61 p.

Hay, D. E. 1985. Reproductive biology of Pacific herring (Clupea harengus pallasi). Can. J. Fish. Aquat. Sci. 42: 111-126.

Huynh, M. D. and T. Howard. 1981. Comparative yield and quality of roe processed from brined and frozen herring. Tech. Rep. 5. Division of Fisheries Technology, B. C. Research, Vancouver, B. C.

Kreiberg, H., J. R. Brett and A. Solmie. 1982. Roe herring impoundment research - report on the 1981/1982 studies. Can. Tech. Rep. Fish. Aquat. Sci. 1149: 45 p.

Peryam, D. R. and F. J. Pilgrim. 1957. Hedonic Scale Method of measuring food preferences. Food Technology, Vol. 11, No. 9, pp. 9-14.

Tsuyuki, H. and J. Y. Cheng. 1985. The effect of maturity, handling and processing conditions, freezing methods, on the development of fragile roe and on roe yield from impounded and wild stocks of herring, 1984. Can. Tech. Rep. Fish. Aquat. Sci. (in prep.)

Tsuyuki, H., J. Y. Cheng, S. N. Williscroft and M. D. Huynh. 1977. Causes of development of sponginess in roe produced from frozen herring. Fisheries and Marine Service, Tech. Rep. 739.

Tsuyuki, H., S. N. Williscroft, J. Cheng and M. D. Huynh. 1979. Roe processing technology. In Semi-Annual Progress Report, p. 19-26. Technology Services Branch, Dept. Fisheries and Oceans, Canada.

Table I. Yield and Grades of roe from impounded herring, Pen H4, P.B.S. 1981

H4 Sampling Date 1981	Roe Yield %, w/w 1°* (mature ♀)	No. of ♀ Examined	Grade (%, no. of skein) I	II	III	IV	V unripe roe	Remarks
Mar. 5	23.2	50	40	14	8	6	32	Unripe roe proportion high.
9	22.1	50	38	16	12	4	30	
12	23.0	50	44	22	8	2	24	Slightly deeper in colour.
16	23.1	50	38	20	12	12	18	
18	22.3	40	60	10	13	2	15	Normal in quality.
19	22.7	40	63	10	10	0	17	" " "
20	23.4	100	52	13	14	5	16	" " "
23	22.6	40	65	7	10	5	13	" " "
26	22.5	50	54	28	8	2	8	" " "
30	23.1	50	64	28	4	2	2	" " "
Apr. 2	23.5	50	54	36	6	2	2	
6	22.2	50	70	28	2	0	0	
9	22.7	80	54	28	14	3	1	Some roes were slender. Partially spawned out.
[illegible]	25.0	50	74	14	10	2	0	Samples have been frozen and processed.
21	26.0	50	70	16	8	6	0	Samples have been frozen and processed.
23	21.7	50	64	18	12	6	0	
May 7	25.5	100	67	12	-	-	0	About 21% spawned out.

* 1° - primary processing

Table 2. Yield and grades of roe from impounded herring, Pen H7 (L-90-1). 1982.

H7 Sampling Date 1982	Roe Yield (mature ♀ %, w/w) 1°	2°**	No. of ♀ Examined	Grade (%, no. of skein) I	II	III	IV	V unripe roe	Remarks
Jan. 28	-		> 50	-	-	-	-	100	Unripe roes, small in size.
Feb. 24	-		> 50	-	-	-	-	100	About 60%, normal in size.
Mar. 1*	23.0	28.6	95	3	12	2	1	82	
4	19.9	25.0	109	36	21	3	3	37	
8*	25.9	32.7	90	38	21	12	2	27	Unripe roe proportion still high.
11	23.5	27.4	74	53	22	4	2	19	
15									
18	21.3	23.6	100	57	17	10	3	13	All unripe roe were small in size.
23*	26.2	32.4	64	64	22	9	3	2	Normal in quality.
25	21.7	25.2	112	39	32	18	7	4	" " "
29*	26.7	30.6	78	55	34	9	2	0	" " "
Apr. 1	22.9	26.4	82	57	24	16	2	1	" " "
5*	27.8	33.5	84	51	34	12	3	0	" " "
8*	26.4	30.6	83	35	47	16	2	0	" " "
15*	-		100	-	-	-	-	-	Spawned out sample.
15*	26.3	32.1	75	31	43	26	-	0	From Pen L-90-2
22*	24.9	30.9	58	39	32	29	-	0	some partially spawned sample observed.
29	19.4	22.0	60	33	24	37	3	-	About 3% spawned out.
May 12	19.3	21.3	64	31	25	17	2	-	About 25% spawned out.

*Freeze-processed. **2° - secondary processing.

Table 3. Proximate composition of impounded herring roe (fresh-frozen).

Sampling Date 1982	Moisture	Protein	Ash	Lipid
Feb. 24	67.2 ± 1.1(6)*	26.2 ± 1.0(6)	1.3 ± 0.1(6)	3.8
Mar. 4	67.7 ± 0.9(6)	23.9 ± 1.5(6)	1.9 ± 0.4(4)	4.5
11	69.2 ± 5.2(6)	22.4 ± 4.2(6)	1.3 ± 0.2(4)	6.0
18	72.9 ± 5.5(5)	19.3 ± 3.7(5)	1.3 ± 0.2(5)	3.7
25	77.8 ± 0.9(5)	16.9 ± 1.4(5)	1.0 ± 0.1(5)	2.9
Apr. 29	76.7 ± 0.9(6)	18.2 ± 1.0(6)	1.0 ± 0.1(5)	3.1
May 12	76.4 ± 1.8(6)	18.3 ± 1.4(6)	1.0 ± 0.1(6)	2.9

* Mean ± S.D.(N) % wet weight

Lipid - average of triplicate samples

Table 4. Processed roe composition from impounded herring roe.

	Brine Processed	Freeze-Processed
Moisture content (%, wet weight)	61.97 ± 1.69(12)	66.79 ± 1.08(12)
Protein (%, w/w) (N x 6.25)	17.17 ± 0.68(11)	13.03 ± 0.87(11)
Ash (%, wet weight)	17.13 ± 0.89(12)	17.80 ± 0.87(12)

Mean ± S.D. (N)

Brine processed roes are from samples of March 25 and April 29, 1982.

Freeze-processed roes are from samples of March 23 and April 22, 1982.

Table 5. Roe yield from impounded herring.

Sampling Date (1982)	No. of ♀ Examined	Roe Yield, % w/w: Primary[1] Processing	Roe Yield, % w/w: Secondary[2] Processing	Remarks
Mar. 4	109	19.9	25.0	Final roe yield from
11	74	23.5	27.4	brine-process method
18	100	21.3	23.6	Mean: 24.93%
25	112	21.7	25.2	S.D.: 1.93
Apr. 1	82	22.9	26.4	N: 6
29	60	19.4	22.0	
Mar. 1	95	23.0	28.6	Final roe yield from
8	90	25.9	32.7	freeze-process method
23	64	26.2	32.4	Mean: 31.43%
29	78	26.7	30.6	S.D.: 1.56
Apr. 5	84	27.8	33.5	N: 8
8	83	26.4	30.6	t: 6.974
15	75	26.3	32.1	df: 12
22	58	24.9	30.9	

[1]Yield after submersion in 11% brine to firm the roe or after freezing the herring.

Brine-process method: Mean: 21.24% S.D. 1.61, n=6.
Freeze-process method: 25.90% S.D. 1.42, n=8.

[2]Yield after final curing in fortified saturated brine.

Table 6. Comparative weight changes in roe during processing from fresh, frozen and 11% brine firmed herring

Herring Treatment	Yield (%)		Roe Weight (kg)		
	Initial	Final	Initial	Final	% increase
Fresh[a]	25.91	26.34	4.16	4.23	1.68
11% brine - 3 days	22.75	25.32	11.00	12.24	11.27
Frozen - 5 weeks	25.55	30.23	9.82	11.62	18.33
				11.77*	19.86
Fresh[b]	23.65	24.15	5.70	5.82	2.11
11% brine - 3 days	22.65	22.96	7.25	7.35	1.38
Frozen - 3 weeks	23.49	26.36	3.85	4.32	12.21
Fresh[c]	21.70	22.00	4.90	4.93	0.60
11% brine - 5 days	20.30	21.20	5.25	5.48	4.38
Frozen - 8 weeks	23.96	27.88	5.20	6.05	16.40

[a] Part of approximately 240 kg of herring from Kitkatla Inlet, caught on 31 March, 1978. Post mortem age, up to 24 hours before processing.

[b] Part of approximately 700 kg of seine herring from Blaine, Washington, U.S.A., caught on 24 April, 1978. Post mortem age, 18 - 22 hours before processing.

[c] Part of approximately 360 kg of seine herring from Blaine, Washington, U.S.A., caught on 24 April, 1979. Post mortem age, 16 - 20 hours before processing.

* Roe weight after 3 weeks storage in saturated brine.

% yield - w/w based on females only.

Table 7. Yield and grades of roe from impounded herring.

Sampling Date 1983	Roe Yield (mature ♀ %, w/w) 1°	2°*	No. of ♀ Examined	Grade (%, no. of skein) I	II	III	IV	V unripe roe	Remarks
Feb. 22	-		> 50					100	Mostly small in size from Pen H4
Mar. 1	-		> 50		14			86	From Ruxton field site.
4	25.8	28.2	88	26	10	7		57	6% near ripe stage.
7	27.0	29.8	89	33	38	7		22	Unripe roe proportion still high.
10	28.4	30.1	101	34	31	12		23	" " " " "
15	27.2	29.6	107	35	27	20	5	13	Normal in quality.
18	27.1	29.8	118	42	43	10		5	
22	25.8	29.0	105	30	29	35	1	5	1% partially spawned sample.
29	27.8	31.1	126	42	32	26		0	From Pen H4.
Apr. 6	26.5	29.4	101	40	31	27		3	Normal in quality.
14	23.6	25.5	122	32	28	40		0	Brine-processed 5% partially spawned sample.
19	30.3	34.4	123	48	28	24		0	
26	29.7	34.1	112	45	28	27		0	11% partially spawned sample.
May 2	29.2	34.5	99	29	40	21	10	0	17% of fish spawned out.

*1° - primary processing. 2° - secondary processing

Table 8. Proximate composition of impounded herring roe (fresh).

Sampling Date 1983	Moisture	Protein	Ash	Lipid
Feb. 22	68.3	25.1	1.2	3.5
Mar. 1	68.8	24.3	1.3	4.6
7	74.3	20.1	1.1	3.3
15	76.4	18.5	1.0	2.0
22	78.8	16.4	0.9	2.1
Apr. 14	77.7	17.3	1.0	1.9

Average of duplicate samples

Table 9. Values (L, a, b) of Hunter Colorimeter for processed herring roe. Mean ± SD (n)

	L	a	b	a/b
Frozen - processed	45.32 ± 0.72 (10)	3.57 ± 0.55	19.17 ± 0.95	0.19
	43.79 ± 0.89 (10)	5.79 ± 0.57	18.20 ± 0.47	0.32
Unfrozen - processed[1]	52.21 ± 0.98 (10)	5.05 ± 0.32	22.99 ± 0.49	0.22
	51.53 ± 1.11 (10)	4.74 ± 0.47	22.62 ± 0.66	0.21
11% brine firmed	47.76 ± 0.84 (10)	6.74 ± 0.23	20.26 ± 0.90	0.33
	42.22 ± 0.49 (10)	6.58 ± 0.36	16.90 ± 0.81	0.39
After 0.2% H_2O_2 treatment[2]	54.46 ± 1.50 (10)	3.12 ± 0.51	21.12 ± 0.58	0.15
Commercial product from: Frozen herring	42.78 ± 0.89 (6)	4.67 ± 0.61	17.86 ± 0.35	0.26
	42.90 ± 1.09 (6)	4.16 ± 0.31	16.71 ± 0.36	0.25
Brine firmed	50.39 ± 0.54 (10)	4.87 ± 0.31	19.85 ± 0.42	0.25
	50.06 ± 0.68 (10)	5.18 ± 0.41	20.07 ± 0.48	0.26
Discoloured roe	30.22 ± 0.73 (8)	9.27 ± 0.67	12.01 ± 0.57	0.77
After 0.2% H_2O_2 treatment	41.61 ± 1.29 (4)	4.42 ± 0.25	15.51 ± 0.73	0.29

1 not yet firmed, soft roe excised carefully from fish with a specially modified scalpel and then processed.

2 roe brightened in 0.2% hydrogen peroxide for 3 - 4 days at 2 to 4°C at a peroxide to roe ratio of 3:1. Rinsed thoroughly with water before colour measurement. Excess hydrogen peroxide destroyed enzymatically.

Table 10. Mean value of firmness and weight of grade I processed herring roe from impoundment.

Sampling Date 1983	Number Tested	Firmness (kg/cm)	Weight (g)
Mar. 18	10	2.75 ± 0.81	28.4 ± 5.80
23	14	2.73 ± 0.64	25.8 ± 3.21
29	15	2.19 ± 0.50	30.97± 6.64
Apr. 14	14	2.92 ± 1.08	28.31± 5.78

Mean value of firmness: 2.65 ± 0.76 kg/cm

Mean value of weight: 28.37 ± 5.36 g per skein

Total tests of processed roe: 53

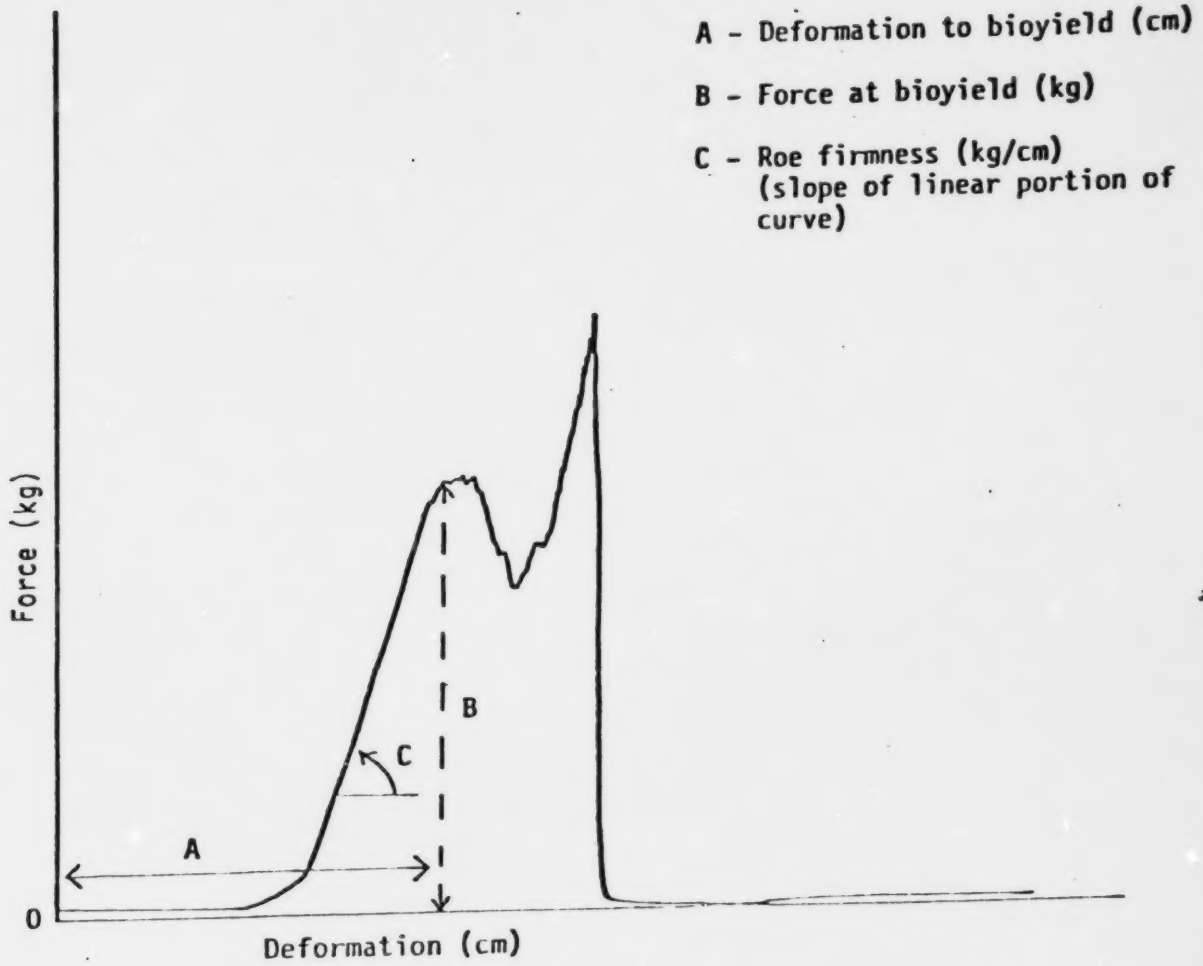

Fig. 1. Typical force-deformation curve of individual processed roe.

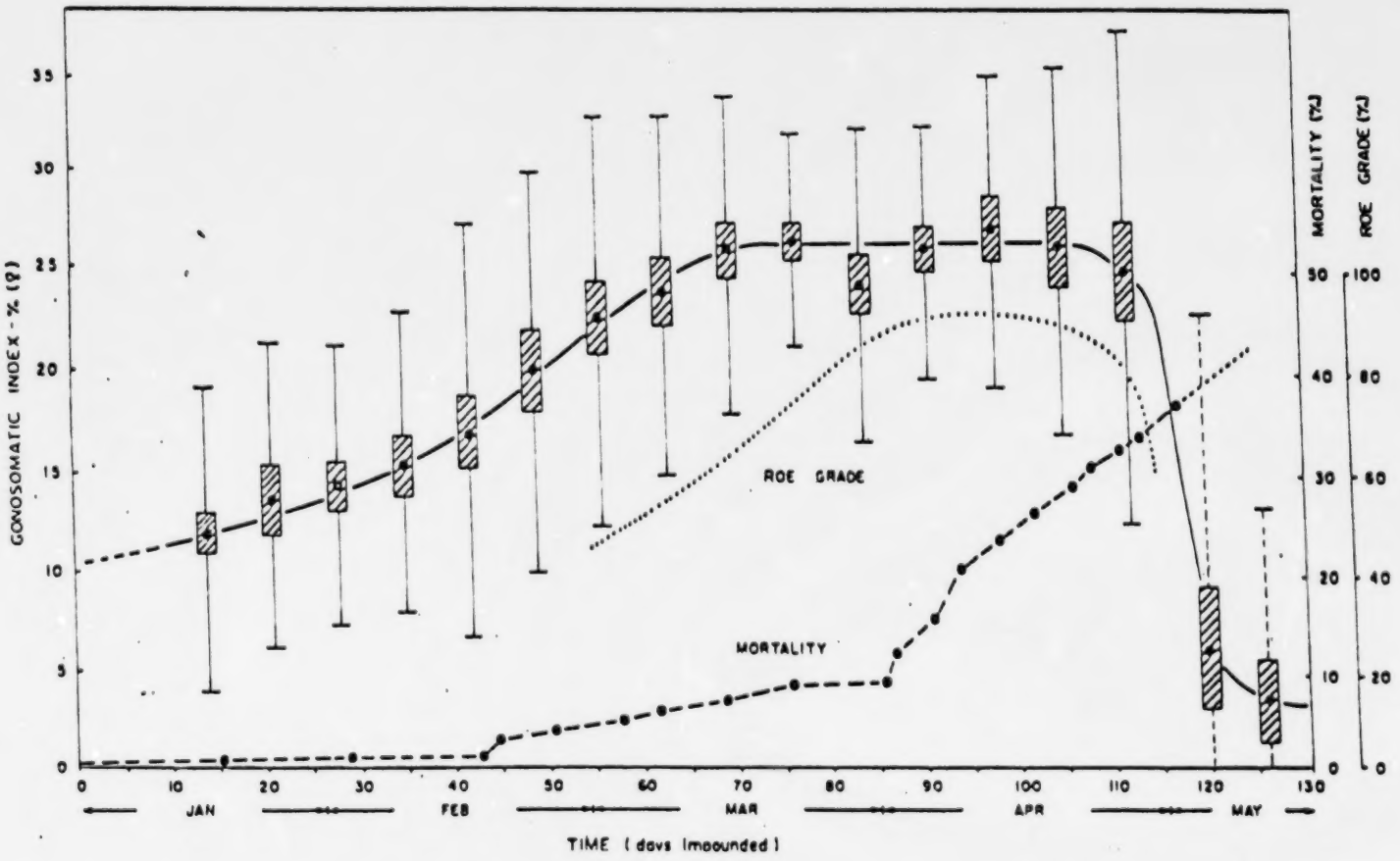

Fig. 2. Increase in gonosomatic index of females caught on January 5th, 1981, and held in netpen H4 (Mean ± 2 SE, ± 2 SD). Maximum percentage (26%) was reached on March 16, 70 days after capture; spawning commenced on April 25th, 40 days later. Roe grade plotted as percent of No. I and No. II combined. Cumulative mortality curve included for comparison. This figure reproduced with the permission of Dr. J. R. Brett from Brett and Solmie, 1982.